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COLOURING OF COFFEE GRAINS RELATED TO DIFFERENT RELATIVE HUMIDITY OF THE DRYING AIR AFTER PARTIAL DRYING

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ABSTRACT

Changes in color of coffee grains are indications of occurrence of oxidative processes and biochemical changes, which can alter the taste and aroma precursors of the grains, resulting in lower beverage quality. Thus, the aim of this study was to evaluate the color characteristics of peeled coffee grains subjected to different relative humidity of the drying air after partial drying. Coffee (*Coffea arabica*) fruits were harvested in the cherry stage and were wet processed. The treatments were the results of the combination of three dry bulb temperatures and three dew point temperatures. The control of dew point temperature was performed only after the grains reach the partial drying. Considering the T_{bd} of 40°C - 40°C, the reduction of the T_{pd} (2.6°C) increased the grains bleaching, while the increase of T_{pd} (16.2°C) resulted in a more yellowish-red. T_{bd} of 40°C - 35°C and 35°C - 35°C are indicated for bluish-green color formation, associated with higher sensory quality. The Color Saturation (C*) of the coffee grains are highly correlated with the *b** color parameter, while the tonality (Hue) is negatively correlated with the *a** color parameter.

Palavras-chave:
coloração
secagem
temperatura de bulbo seco
temperatura de ponto de orvalho
umidade relativa

COLORAÇÃO DE GRÃOS DE CAFÉ EM FUNÇÃO DE DIFERENTES UMIDADES RELATIVAS DO AR DE SECAGEM APÓS MEIA SECA

RESUMO

Alterações na cor dos grãos de café são fortes indícios da ocorrência de processos oxidativos e transformações bioquímicas enzimáticas que alteram a composição dos precursores responsáveis pelo sabor e aroma da bebida, resultando em redução da qualidade. Assim, objetivou-se, neste trabalho, avaliar os parâmetros de cor de grãos de café descascado submetidos a diferentes umidades relativas do ar de secagem após meia seca. Os frutos de *Coffea arábica* foram colhidos no estádio de maturação cereja e processados por via úmida. Os tratamentos foram resultados da combinação de três temperaturas de bulbo seco e três temperaturas de ponto de orvalho. O controle da temperatura de ponto de orvalho foi feito apenas após os grãos alcançarem a meia seca. Para T_{bd} de 40°C - 40°C, a redução da T_{pd} (2,6°C) aumentou o branqueamento dos grãos, enquanto que o aumento da T_{pd} (16,2°C) resultou em uma coloração mais vermelho-amarelada. T_{bd} de 40°C - 35°C e 35°C - 35°C são indicadas para formação da cor verde-azulada, associadas a maior qualidade sensorial. A saturação (C*) da cor dos grãos de café estão altamente correlacionados a coordenada *b**, enquanto a tonalidade (Hue) esta correlacionado negativamente com a coordenada *a**.

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INTRODUCTION

During the post-harvest stages, coffee undergoes changes in its physical characteristics. Harvesting, processing, drying and storage influence the aspects of shape, size and color of coffee beans, the latter being the most important, since it directly interferes with the acceptance or rejection of the product on the market, as the color is directly related with the drink quality (AFONSO JÚNIOR; CORRÊA, 2003).

In the literature, color is associated with sensory and physical qualities, directly influencing the final price of the product. Changes in color are related to oxidative processes and biochemical transformations that will negatively affect the sensory quality of the coffee drink (BORÉM *et al*. 2013; MOREIRA, 2015).

The color has been studied for some years mainly due to the occasional undesirable bleaching of coffee, due to the increase in the L * coordinate, which is associated with the luminance of the beans (AFONSO JÚNIOR; CORRÊA, 2003). Typically, coffee beans have a desirable bluish-green color, characterized by a reduction in the chromatic coordinates a * and b * (CORRÊA *et al*. 2002). However, this color may gradually change to yellow-green, yellow or whitish, mainly due to inadequate drying and storage operations (CORADI *et al*. 2008; LEITE *et al*. 1998; RIBEIRO *et al*. 2011). Other factors, such as damages suffered by the product at any post-harvest stage, light, relative humidity, water content, storage time and type of packaging for storage also influence the color changes of the grains (BORÉM *et al*. 2013; CORADI; BORÉM, 2009; ISMAIL *et al*. 2013; NOBRE, 2005).

Regarding the drying process, Corrêa *et al*. (2002) found that the increase in the drying air temperature affected the color of the coffee beans, mainly reducing the intensity of the green color, regardless of the type of processing used.

High water reduction rates promoted by higher drying temperatures can cause discoloration, stains, cracks and breaks in the grains (GUNASEKARAN *et al*. 1985, cited by CORRÊA *et al*. 2002; BORÉM, 1992), as well as the leakage of intercellular fluid caused by rupture of the cell membrane. However, low rates of water reduction may also be detrimental to the quality of the coffee, since high initial water contents increase the risk of deterioration.

Ondier, Siebenmorgen and Mauromoustakos (2010) evaluated the drying rate of rice grains, submitted to drying with low temperatures and relative humidity between 19% and 47%. The authors observed that, for the same temperature, the reduction in relative humidity significantly reduced the drying time. In addittion, the color of the grains was not negatively affected by the increase in the drying rate, indicating the use of this air dehumidification technique for drying rice.

Moreira (2015), studying the color of the endosperm of coffee beans submitted to dry processing and different drying methods, observed that the use of drying air with low relative humidity did not promote color differences in the beans when compared to drying in a terrace or in a rotary dryer, however the drying process was faster.

Therefore, evaluating the color of coffee beans is of great importance to detect changes caused by different post-harvest technologies. Thus, the objective of this work was to evaluate the color parameters of peeled coffee beans submitted to different relative humidity of the drying air after partial drying.

MATERIAL AND METHODS

The analyses were performed on *Coffea arabica* L. cv. Catuaí Vermelho, harvested in the municipality of Nepomuceno, MG, during the 2018 harvest.

The selective harvesting of the fruits was performed manually, selecting only fruits in the cherry ripening stage. The fruits were subjected to density separation to remove fruits of lower specific mass (dry, brocade and badly granulated) and a new manual selection was performed for the removal of immature and remaining overripe fruits.

After the manual selection, the coffee was processed in a wet way, resulting in the portion of peeled coffee, with the exocarp and part of the mesocarp removed mechanically, with a water content of 1.56 ± 0.06 (db).

Nine drying treatments were performed in a 3x3 factorial scheme, with three dry bulb temperatures (40 ° C; 40 °C - 35 °C and 35 °C) and three dew point temperatures (2.6 ° C; 10, 8 ° C and 16.2 ° C). Two more treatments were performed without dew point temperature control, with two dry bulb temperatures (40 ° C and 35 ° C). For each treatment, four repetitions were performed. Depending on the combinations between dry bulb temperature and dew point temperature, different relative humidity (RH) of the drying air were obtained (Table 1).

The drying operation took place in two stages for treatments numbered from one to nine. The first stage started at the moment of the grains entering the dryer and ended when the product reached approximately 0.42 ± 0.01 db. During the first stage there was no control of T_{pd}, neither the RH of the drying air. The second stage started after the product reached 0.42 ± 0.01 db, with T_{pd} control and consequently RH control. The T_{bd} were altered in relation to the first stage, only for treatments four, five and six, remaining unchanged until the grain mass reached the water content of 0.12 ± 0.01 db.

The drying system was composed of an air conditioning system coupled to a fixed layer dryer (Figure 1). The air characteristics were controlled by a laboratory air conditioning system (SCAL), a model proposed by Fortes *et al*. (2006). This equipment allows the control of the flow, dry bulb temperature (T_{bd}), dew point temperature (T_{pd}) and the relative humidity (RH) of the drying air with precision. In order to obtain the lowest dew point temperatures and, consequently, the lowest relative humidity, before SCAL, the air was pre-conditioned by a refrigeration system composed of three air conditioning units. For all treatments, the drying air speed was kept constant at 0.33 $m.s^{-1}$, corresponding to a flow of 20 $m^3.min^{-1}.m^{-2}$.

The color index of the coffee beans endosperm was determined by directly reading the coordinates L *, a * and b * in a Minolta colorimeter model CM-5, as described by Nobre (2005).

This system interprets and standardizes colors using the concept of the three-dimensional axes L *, a * and b *, transforming colors into a three-number pattern. The L * axis indicates the luminosity, and its values vary from 0 to 100, corresponding to black and white respectively. The

Table 1. Dry bulb temperature, dew point temperature and relative humidity of the drying air for partial drying and complementing drying

Treatment	First Part (Partial drying) Initial water content – 1.56±0.01 db Final water content – 0.42±0.01 db	Second Part (Complementing drying) Initial water content – 0.42±0.01 db Final water content – 0.12±0.01 db		
	T_{bd} (°C)	T_{bd} (°C)	T_{pd} (°C)	RH (%)
1	40	40	2.6	10.0
2	40	40	10.8	17.5
3	40	40	16.2	25.0
4	40	35	2.6	13.1
5	40	35	10.8	23.0
6	40	35	16.2	32.7
7	35	35	2.6	13.1
8	35	35	10.8	23.0
9	35	35	16.2	32.7
10	40	40	-	-
11	35	35	-	-

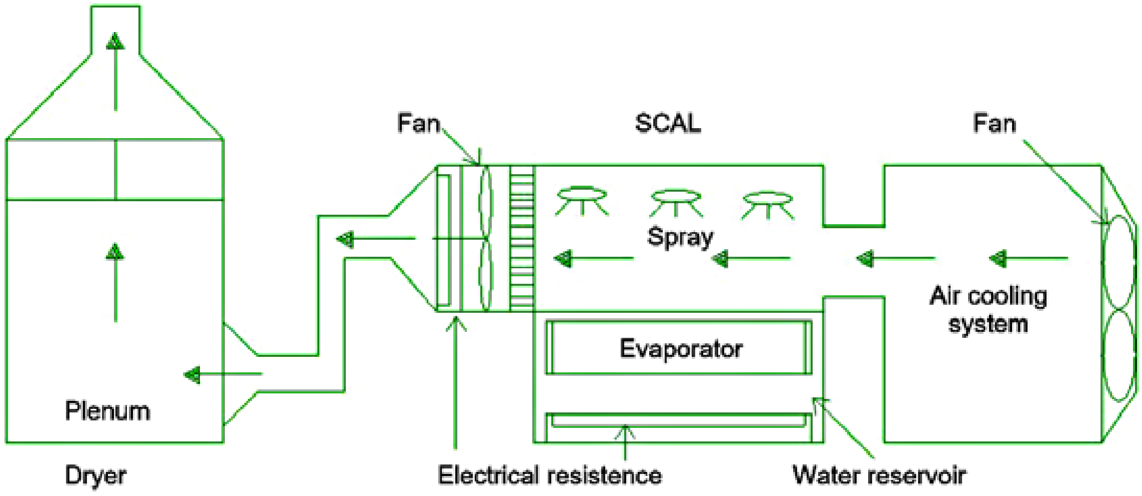

Figure 1. Drying system used for the mechanical drying of coffee. Source: Adapted from Alves (2013)

axes a * and b * indicate the directions that the color can take. Positive values of a *, correspond to red and negative values of a * correspond to green. The positive values of b * correspond to yellow and negative values of b * correspond to blue.

The Hue angle and the Chroma (C *) were also directly determined. The Hue parameter is a cylindrical coordinate that represents the hue ranging from red (0º), yellow (90º) and green (180º) and is useful in the interpretation of color differences (CAMELO; GÓMEZ, 2004; VOSS, 1992). The chroma is the purity or saturation of the color (SPÓSITO *et al*. 2004) and represents the distance from the luminosity axis (L *). The extreme chroma represents the maximum that a color can contain of itself. The samples were placed in Petri dishes, resulting in a grain blade of approximately 17 mm, and for each repetition of drying, three repetitions were performed in the colorimeter, with the grains being revolved at each repetition.

All data were subjected to analysis of variance and the *Scott Knott* test for comparison of means, at 5% probability level.

RESULTS AND DISCUSSION

The mean values referring to the analyzed color variables are described in Table 2. We can observe that higher values of the L * coordinate (luminance), related to the bleaching of the coffee, were obtained by treatments that resulted in a higher average rate of water reduction; which means, treatments with a combination of T_{bd} of 40°C - 40°C, with T_{pd} of 2.6 ° C and without T_{pd} control. We can also verify in Table 3 that these treatments were also the ones that obtained the lowest sensory scores. Marques (2006) states that higher drying temperatures break the cell membrane structures, causing the overflow of oils and compromising the quality of the coffee with the oxidation processes, causing greater bleaching of the beans. The L * coordinate values found in this work ranged from 48.65 to 51.01, similar to values found in the literature for coffees (CORADI *et al*. 2008; ABREU *et al*. 2015).

The coordinates a *, b * and C *, generally have the same pattern, with the highest values observed for treatments with a combination of T_{bd} 40 °C - 40° C and with T_{pd} control, while the lowest values were obtained by treatments with less T_{bd} combination. This pattern can be reinforced by data presented in Table 4, which shows the analysis of correlation between the analyzed color variables, showing the high correlation between variables b * and C *, and a moderate correlation between variables a * and b * and between * and C *, all with a high level of significance ($p < 0.05$). The values of coordinates a * and b * are similar to those found for coffee endosperm by other authors (CORADI *et al*. 2008; ABREU *et al*. 2015).

Table 2. Mean values of the coordinates L *, a *, b *, C * (saturation) and Hue of coffee beans submitted to different combinations of dry bulb temperatures and dew point

T	$T_{bd-fp-sp}$ (°C-°C)	T_{pd-sp} (°C)	*L**	*a**	*b**	C* (sat)	Hue (ton)
1	40-40	2.6	50.51 a	0.99 c	17.27 b	17.30 b	86.73 a
2	40-40	10.8	49.91 b	1.11 c	17.47 b	17.50 b	86.37 a
3	40-40	16.2	49.82 b	1.55 a	17.90 a	17.97 a	85.05 c
4	40-35	2.6	49.34 c	1.11 c	16.99 c	17.03 c	86.26 a
5	40-35	10.8	49.20 c	1.17 c	16.83 c	16.87 c	86.04 a
6	40-35	16.2	49.40 c	1.31 b	16.99 c	17.04 c	85.58 b
7	35-35	2.6	49.27 c	1.28 b	16.53 d	16.58 d	85.57 b
8	35-35	10.8	49.19 c	1.08 c	16.69 d	16.72 d	86.31 a
9	35-35	16.2	48.65 c	1.02 c	16.30 d	16.33 d	86.41 a
10	40-40	-	51.01 a	1.08 c	17.03 c	17.06 c	86.38 a
11	35-35	-	49.42 c	1.18 c	16.91 c	16.95 c	86.02 a
CV (%)			0.77	7.58	1.58	1.59	0.31

fp = first part; sp = second part. Means followed by the same letter in the column do not differ significantly by the Scott-knott test (p> 0.05).

Table 3. Sensory scores of the coffee beans drink submitted to different combinations of dry bulb temperatures and dew point

Treatment	$T_{bd-fp-sp}$ (°C - °C)	T_{pd-sp} (°C)	Total Score
1	40-40	2.6	83.7 c
2	40-40	10.8	83.0 c
3	40-40	16.2	85.5 a
4	40-35	2.6	83.3 c
5	40-35	10.8	85.5 a
6	40-35	16.2	84.5 b
7	35-35	2.6	84.5 b
8	35-35	10.8	83.3 c
9	35-35	16.2	85.0 a
10	40-40	-	83.7 c
11	35-35	-	84.3 b
CV (%)			0.56

fp = first part; sp = second part. Means followed by the same letter in the column do not differ significantly by the Scott-knott test (p> 0.05).

Table 4. Correlation analysis between the color variables of coffee beans submitted to different combinations of dry bulb temperatures and dew point

	*L**	*a**	*b**	C*	Hue
*L**	100.000	0.02666 0.8636+	0.60174 <0.0001+	0.59471 <0.0001+	0.09822 0.5259+
*a**	0.02666 0.8636+	100.000	0.50419 0.0005+	0.52315 0.0003+	-0.98137 <0.0001+
*b**	0.60174 <0.0001+	0.50419 0.0005+	100.000	0.99974 <0.0001+	-0.33176 0.0278+
C*	0.59471 <0.0001+	0.52315 0.0003+	0.99974 <0.0001+	100.000	-0.35247 0.0189+
Hue	0.09822 0.5259+	-0.98137 <0.0001+	-0.33176 0.0278+	-0.35247 0.0189+	100.000

+p-valor

It is important to emphasize that, when analyzing the value of coordinates a * and b *, it should be considered that lower values tend to green and blue in coffee beans (desirable color to the product), while higher values tend to red and yellow (undesirable). The results found in this work indicate an approximation of the bluish green color in coffees submitted to a lower T_{bd} combination (35°C - 35°C). This result was also observed by Corrêa *et al*. (2002), who found that the higher the drying temperature, the lower the intensity of the green color for dry and wet processed coffees. Abreu *et al*. (2015), also related the bluish green color to higher quality coffees.

In Table 4, we can also highlight the moderate and significant correlation between the variables L * and b * and between L * and C *. Considering the variables a * and Hue, they presented high negative correlation, which means that they present an inverse behavior, higher values of one variable result in lower values of the other. However, when analyzing the means test, no pattern is observed between the values.

In general, coffees that showed lower values of color variables, which means, lower bleaching level and greater proximity to the bluish green color, showed better results in sensory quality assessments. Changes in color are strong indications of the occurrence of oxidative processes and enzymatic biochemical transformations that alter the composition of the precursors responsible for the taste and aroma of the drink, resulting in reduced quality (ABREU *et al*. 2015; BORÉM *et al*. 2013; ISQUIERDO *et al*. 2011; RENDÓN *et al*. 2014; RIBEIRO *et al*. 2011).

CONCLUSION

Under the conditions in which the present work was developed, we can conclude that:

- Using the combination T_{bd} of 40 °C - 40 °C, the reduction of the RH of the drying air by reducing T_{pd} (2.6 ° C) increases the bleaching of the grains, while increasing the T_{pd} (16.2 °C) increases the coordinate values a * and b *, resulting in a more yellow-red color.
- Combinations of T_{bd} of 40°C - 35°C and 35°C - 35 °C are indicated for the formation of blue-green characteristics, which in the literature are associated with greater sensory quality.
- The saturation (C *) of the coffee beans color is highly correlated to the b * coordinate, while the hue (Hue) is negatively correlated with the a * coordinate.

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